بسم الله الرحمن الرحيم

Fuzzy Control Course

Lec 1

Introduction

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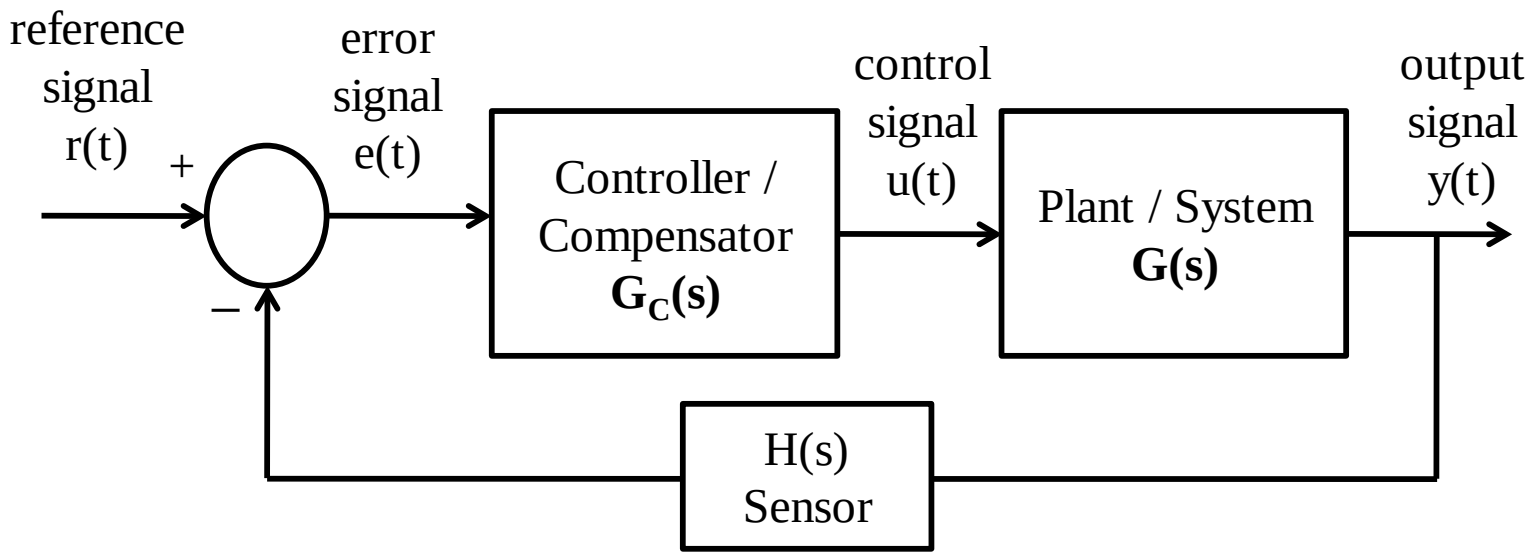
Common Structure of Controller-Plant



A Common Structure of continuous-time Controller-Plant

Common Classification of Controllers

Controllers can be classify to :

1. Classical (or traditional) Controllers
2. Modern Controllers
3. ON-OFF Controllers (sequence control) or two position controllers
4. Computational Intelligence Controllers

1- Classical / traditional Controllers

- PI Controller (improves the steady-state error)
- PD Controller (speeds up the system response and reduces the system over shot)
- PID Controller
- Phase Lead Controller (As PD)
- Phase Lag Controller (As PI)
- Phase Lead-Lag Controller (As PID)

2- Modern Controllers

- State Feedback Control (Pole placement Design)

$$u(t) = -K\,x(t)$$

- State Estimator (observer) Design

3- ON-OFF Controllers (Sequential Control)

Sometimes, the control element has only two position either it is fully closed or fully open (1 or 0) (energized or de energized). This control element does not operate at any intermediate position, i.e. partly open or partly closed position. This type of controllers is known as on-off controllers or two position controllers.

As an Examples of these controllers:

- Programmable Logic Controller (PLC)
- Microcontrollers

4- Computational Intelligence Controllers

Controllers that used the following Fields :

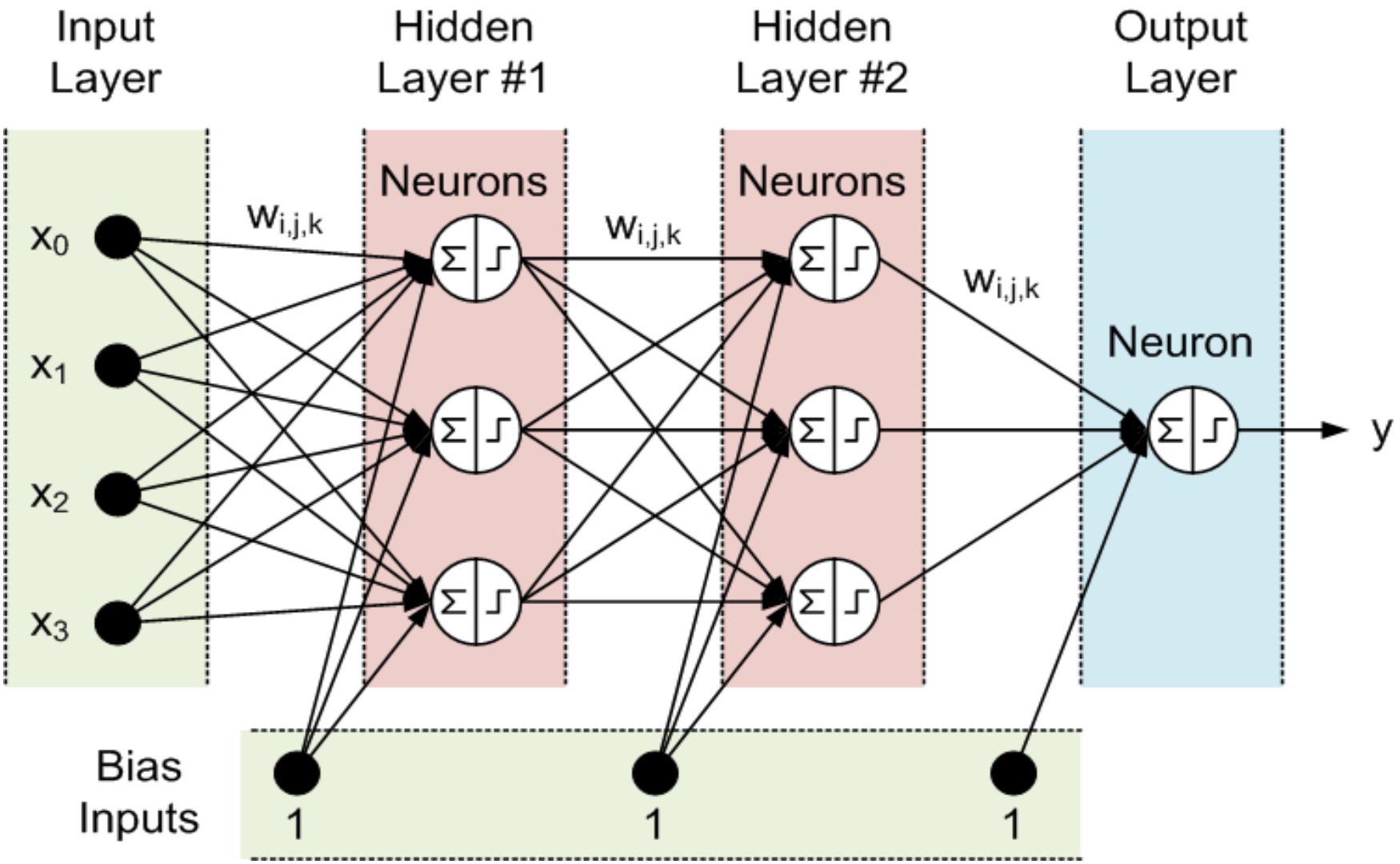
1. Fuzzy Logic (FL) / Fuzzy Control (FC)
2. Neural Networks (NN)
3. Adaptive Neuro Fuzzy Inference System or,

   Adaptive Network-based Fuzzy Inference System or,

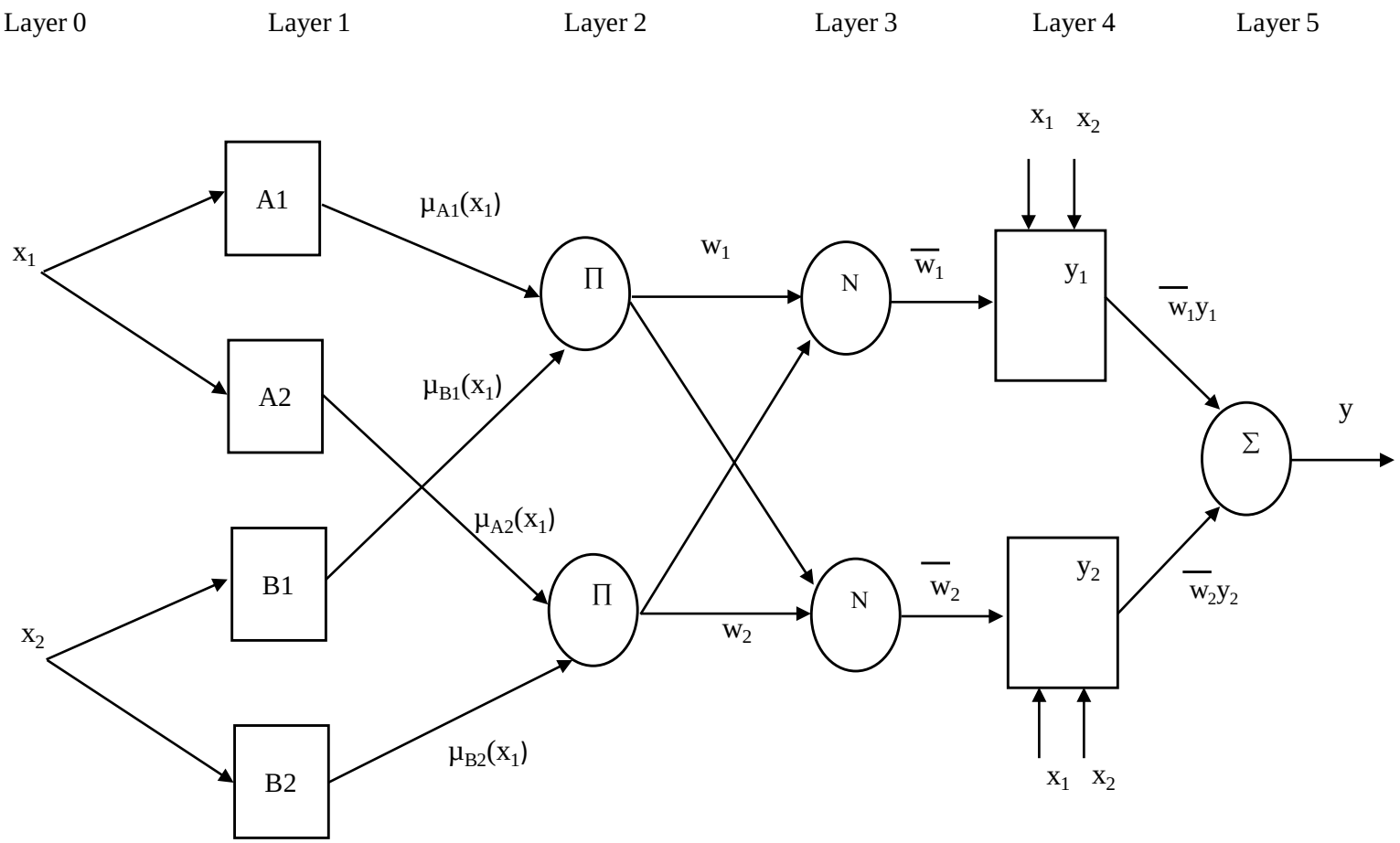
   ANFIS.

4- Computational Intelligence Controllers

The ANFIS is a fuzzy system which is modelled in the form of the artificial neural network. A learning algorithm can be applied to a fuzzy system to train the system.



The Neural Network Structure



The ANFIS structure with two inputs, two rules and one output

4- Computational Intelligence Controllers

4. Evolutionary Computation:

Heuristic Algorithms Based on the principles of Darwinian evolution observed in nature. Example of these algorithms:

- Genetic algorithm (GA)
- Differential Evolution Algorithm (DE)
- Particle swarm optimization (PSO)
- Fish Swarm Algorithm (FSA)
- Ant Colony Optimization Algorithm (ACO)
- Artificial Bee Colony Algorithm (ABC)
- Shuffled frog-leaping algorithm (SFLA)

Limitations of Conventional Controllers

1. System nonlinearity:

Nonlinear systems are computationally intensive and have complex stability problems.

2. System uncertainty (Unknown Systems):

A system does not have accurate models due to unknown parameters and lack of perfect knowledge.

3. Uncertainty in measurements:

Uncertain measurements due to: modeling error (in case of approximation or estimation process), Parameter variations, and stochastic noise.

Limitations of Conventional Controllers

4. Temporal behaviour :

Systems, controllers, environments and their constraints vary with time. Moreover, time delays are difficult to model.

5. Multivariables , multiloops and environment constraints :

Multivariate and multiloop systems have complex constraints and dependencies.

6. Imprecise / vague knowledge of human experts

Advantages of Fuzzy Controllers

1. More Robustness:

Fuzzy controllers are more robust than PID controllers because they can cover a much wider range of operating conditions than PID can, and can operate with noise and disturbances of different natures.

2. Cheap in Cost:

Developing a fuzzy controller is cheaper than developing a model-based or other controller to do the same thing.

Advantages of Fuzzy Controllers

3. Customizable:

As it is easier to understand and modify their rules, which not only use a human operator's strategy but also are expressed in natural linguistic terms.

4. Easy to Design and implementation:

It is easy to learn how fuzzy controllers operate and how to design and apply them to a specific application.

Fuzzy Controllers Application

1. Consumer Products:

- Washing Machines
- Microwave Ovens
- Rice Cookers
- Vacuum Cleaners
- Thermo Pot

Rice Cooker

Thermo Pot

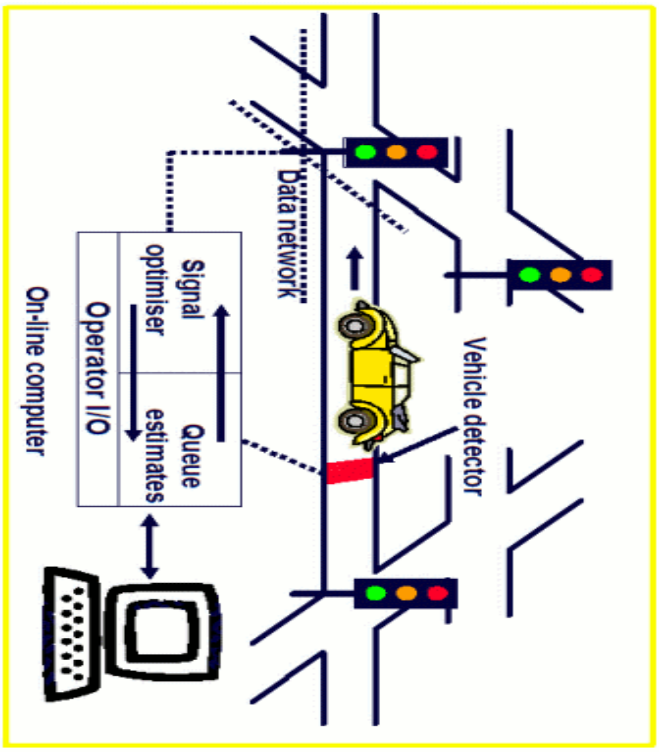
Vacuum Cleaner

Washing Machine

Fuzzy Controllers Application

2. Systems:

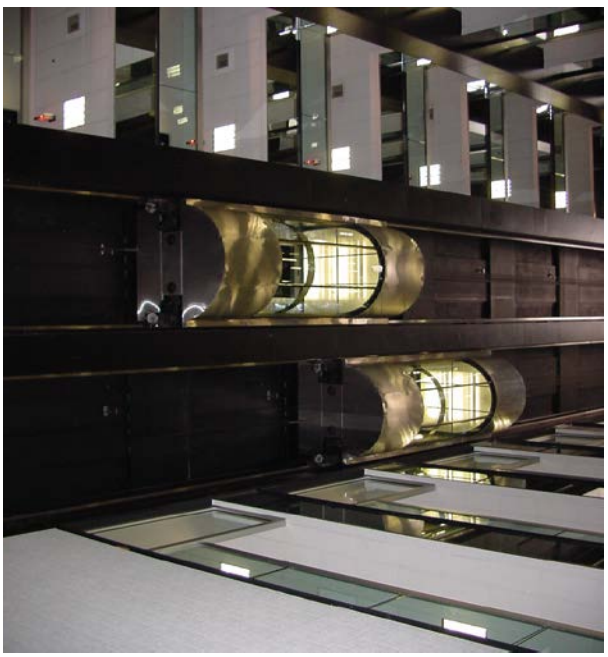
- Fuzzy PID Controllers in several Applications
- Elevators
- Train
- Traffic Control
- Cranes
- Automotive (transmissions, brakes)



Traffic Control

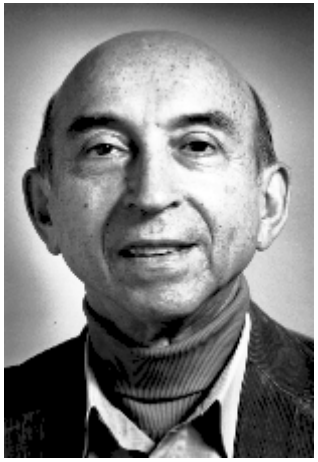
Crane

Automotive



Elevator

Fuzzy Sets and Logic

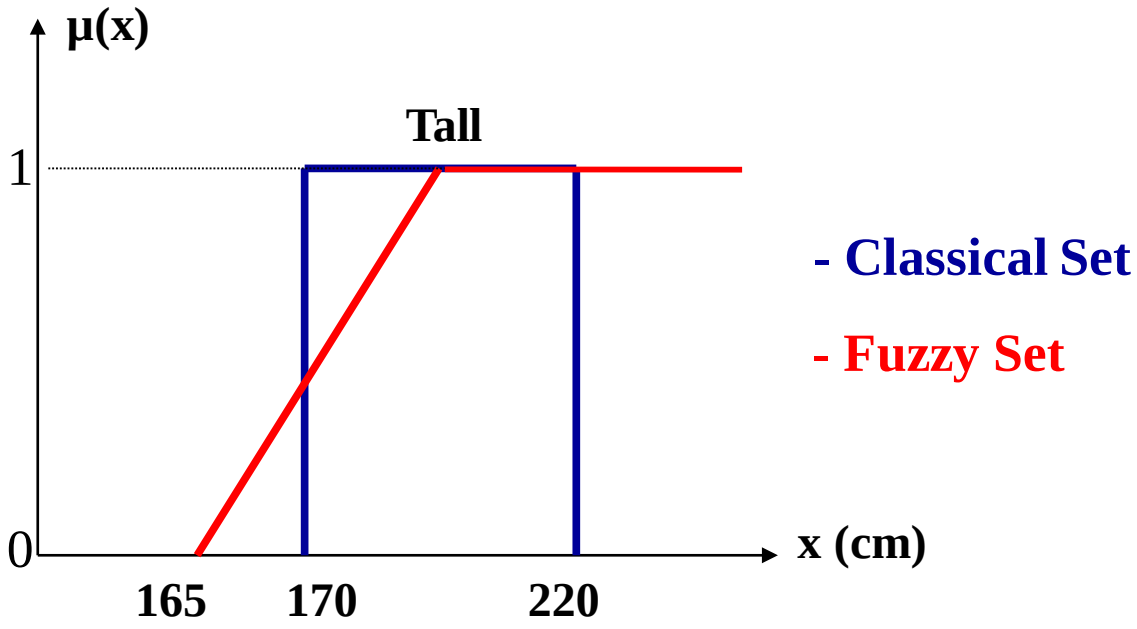


- The term fuzzy is stand for **Imprecise/vague** concepts.
- **Lotfi Zadeh (**professor for computer science at the University of California in Berkeley**)** in 1965 introduced fuzzy sets and logic theory.
- He started an application-oriented approach towards formalization of vague notions.
- He said that: ”The closer one looks at a real-world problem, the fuzzier becomes its solution “.

Difference Between Fuzzy and Classical (Binary) Sets

- The difference between a **binary set** and a **fuzzy set** is that:
  - in a **binary set**, every element is either a member or a non-member of the set (belong or not belong).
  - In a **fuzzy set**, an element can be a member of a set to some degree and at the same time a non-member to some degree of the same set.

Fuzzy Sets and Classical Sets



- **In classical (or binary) set**, membership function takes a degree of either 0 or 1 (True or False) while in **fuzzy sets** membership function takes degree ranging from 0 to 1.

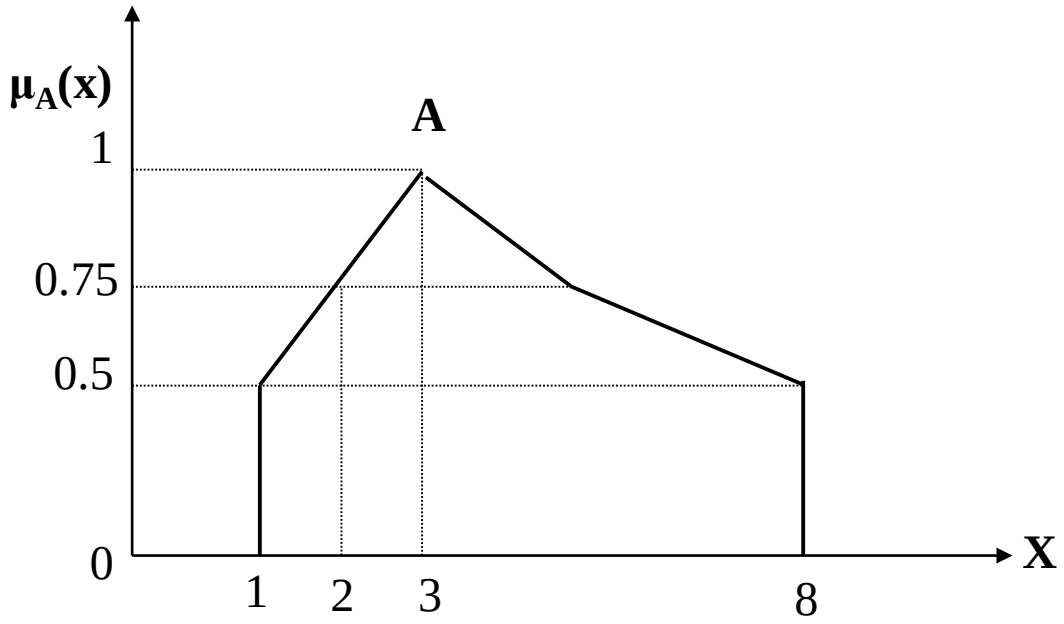
Fuzzy Sets

- A fuzzy set A in X is characterized by a membership function (MF) $\mu_A(x)$ which associates with each point in X a real number in the interval [0 , 1] . The value of $\mu_A(x)$ at x representing the **grade** (or **degree**) of membership of x in A.

- The value of $\mu_A(x) \in [0, 1]$ represents a measure of the degree of belonging of an element to a fuzzy set.

Example:

The following membership function $\mu_A(x)$ represents the fuzzy set A

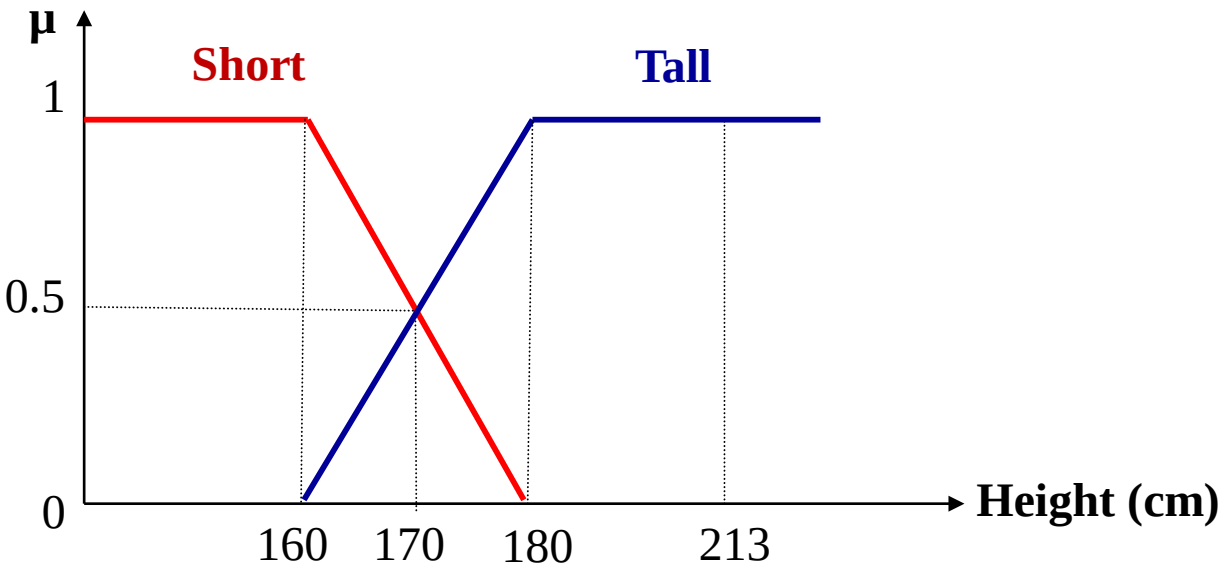


Note that:

- $\mu_A(x) = 0.5$ at $x = 1$
- $\mu_A(x) = 0.75$ at $x = 2$
- $\mu_A(x) = 1$ at $x = 3$

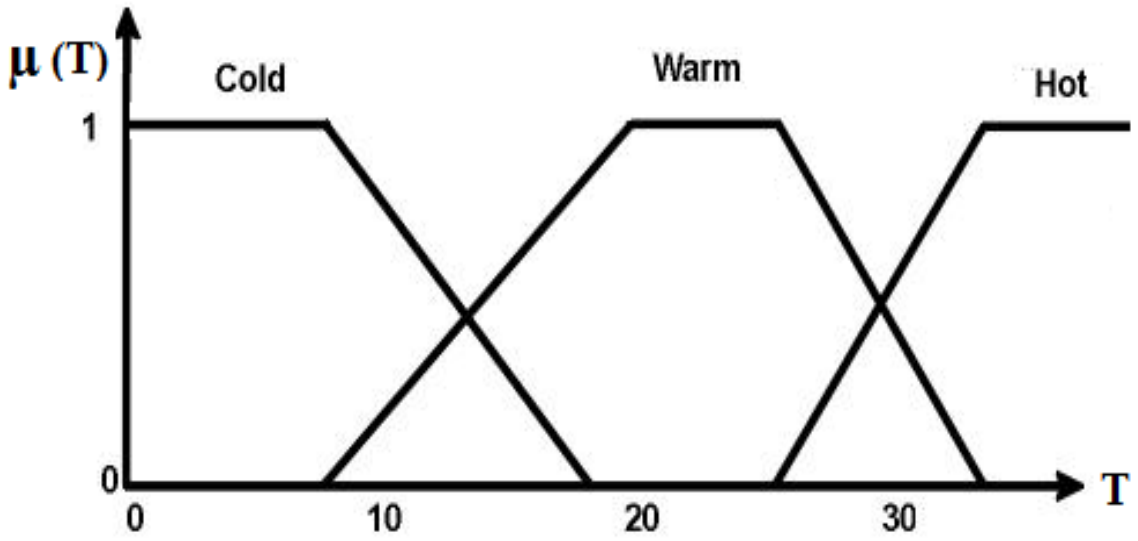
Example of Two Fuzzy Sets

(How tall/short we are?)



Two Fuzzy Sets: Tall and Short

Example: Three Fuzzy Sets Represent Temperature Variations



Three Fuzzy Sets: Cold, Warm and Hot

Reference Books:

1) “ Computational Intelligence ”, Nazmul Siddique and Hojjat Adeli.
2) “ Fuzzy Control ”, Leonid Reznik.
3) “ Fuzzy Controllers ”, Kevin M. Passino and Stephen Yurkovich.
4) “ Foundations of Fuzzy Control ”, Jan Jantzen.
5) “Introduction to Fuzzy Sets, Fuzzy Logic, and Fuzzy Control Systems”, Guanrong Chen and Trung Tat Pham.
6) “ A Course in Fuzzy Systems and Control ”, Li-Xin Wang

Report

Presentation Topics

1) Fuzzy Logic Control for ABS (Anti-lock braking system) Braking System
2) Aircraft Landing Control system using Fuzzy Logic
3) Fuzzy Traffic light Controller
4) Speed Control of DC Motor Using Fuzzy PID Controller
5) Fuzzy Logic Control of Washing Machines
6) Fuzzy logic based automatic braking system in trains
7) Intelligent Air Conditioning System using Fuzzy Logic
8) Fuzzy logic in games
9) Fuzzy controller for rice cooker
10) Intelligent Fuzzy Controller of a Quad-rotor helicopter